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Qualifications for Long-Term Analyses of Technological, Economic, and Other Obstacles Related to Alternative Electricity Supply Futures

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December 14, 2009

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Lawrence Livermore National Laboratory

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December 10, 2009

Executive Summary

Lawrence Livermore National Laboratory (LLNL) is committed to applying our scientific resources to help the nation understand technological, economic and other issues that could affect the location and amount of long-term transmission capacity requirements in the United States. This is particularly important as we increase the use of renewable energy sources and seek to minimize the emission of greenhouse gases. LLNL has an impressive track record in developing new models and analysis tools to better predict the availability of resources and understand the impact of these resources on the electricity grid.

LLNL has developed successful partnerships with academia and industry, including Princeton University, University of California, Seattle City Light, Southern California Edison, and Pacific Gas and Electric. These joint engagements have allowed us to pursue advanced research concepts with the applied and practical operational knowledge of system operators. More recently we have also increased our interactions with state Public Utility Commissions, Independent System Operators, and Western Electric Coordinating Council in areas including wind prediction, grid and control room integration, and real-time analysis of sensor data.

LLNL hosts the Program in Climate Model Diagnosis and Intercomparison (PCMDI). The PCMDI mission is to develop improved methods and tools for the diagnosis and inter-comparison of general circulation models that simulate the global climate. In addition, LLNL has demonstrated techniques for downscaling climate global circulation models to spatial resolutions appropriate for analyzing impacts to regional and local energy systems.

LLNL has recognized the need to better understand the long-term penetration and system-wide effects of intermittent electric generation resources and energy storage. We have extended the META-Net and SMART modeling frameworks to model the behavior of an electric system hour-by-hour, accounting for the intermittent generation of wind and solar generators. This approach correctly captures the correlation between intermittent generation and systems loads, finding the economically optimal structure and operation of the electric generation system. Another LLNL tool, WindSENSE, works to provide control room integration and enables more accurate wind power generation forecasts to help utilities schedule contributions to the grid.

Our response to this Qualification Statement includes these and other subject areas related to near term and emerging needs in the design and operation of the Smart Grid. These grids will enable the maximum utilization of renewable energy resources and the allocation of these resources to provide reliable and cost-effective electricity for the nation.

1. Technical Qualifications

1.1 Atmospheric modeling to support the expansion of wind power production

Background

Domestic wind power production is expanding dramatically, in support of U.S. Department of Energy (DOE) goals of supplying 20% of the nation's electricity from the wind by 2030. While early progress is encouraging, meeting this goal will require not only installing many new wind turbines, but also making significant progress on many technological and scientific fronts involving both the extraction of power from the wind and its integration into the electricity grid.

In 2008, a DOE-sponsored workshop consisting of industry, academia, and research laboratory representatives from around the world defined a set of research priorities to support increased wind-power production. The report prioritized (1) continued improvement of the many atmospheric models applied in wind power production, (2) coupling of different models to improve understanding of scale interactions involving various flow phenomena, and (3) the development of observational testbeds for collecting data focused on wind-energy related data gaps. LLNL possesses a broad base of tools and expertise to address each of these priorities, building on a long history of atmospheric boundary-layer simulation (ABL), global climate change research, and energy flow assessment.

LLNL's Atmospheric Modeling Capabilities

Atmospheric simulations play an important role in wind-power production. Numerical weather prediction (NWP) models predict the future evolution of the wind field. From these predictions, wind power forecasting (WPF) models are used both to predict the power that can be produced, and to integrate wind power into the electricity grid. Computational fluid dynamics (CFD) models are used in turbine design. A limited range of observations are also employed to validate models used in wind energy applications. The existing modeling and observational paradigms, while reasonably successful, rely on simplifications and approximations at all scales but that neglect important details involving both the flow and the extraction of power from it. Improvements to these models and approaches could greatly increase the efficiency, robustness and profitability of wind power production.

Climate Prediction

LLNL hosts the Program in Climate Model Diagnosis and Intercomparison (PCMDI), which has expertise in modeling both regional and global climate change. The PCMDI mission is to develop improved methods and tools for the diagnosis and intercomparison of general circulation models that simulate the global climate. For the past 20 years PCMDI has provided key scientific contributions to the reports written by the Intergovernmental Panel on Climate Change (IPCC), and PCMDI received a special acknowledgment in the 2007 IPCC Fourth Assessment Report for archiving and distributing over 30 terabytes of climate model output. Such expertise can be applied to predict how climate change might affect the distribution of wind and other renewables in the future.

Mesoscale Weather Prediction

LLNL hosts the National Atmospheric Release Advisory Center, a DOE-sponsored emergency-response center that has a long history of using mesoscale simulations to predict the transport of atmospheric contaminant releases. Mesoscale models are applied to limited-area subsets of NWP model domains to better resolve smaller scales of atmospheric motions and to incorporate higher-resolution terrain and land cover data, each of which can significantly improve the accuracy of simulations. While mesoscale simulations are typically applied to improve short-term weather forecasts, they can also be used to better predict and characterize atmospheric flow over regions of interest to wind projects.

Large-eddy Simulations

Large-eddy simulations (LES) represent an additional level of downscaling beyond the mesoscale. LES utilizes sufficiently fine mesh resolution to explicitly resolve the energy-producing scales of turbulence, while parameterizing only the effects of smaller scales. As the larger scales of turbulence primarily determine the distributions of the velocity, temperature and moisture fields, LES can provide much more detailed and accurate simulations of ABL flows and parameters relevant to wind power production. The fine computational meshes utilized by LES likewise permit representation of small-scale terrain features that can be crucially important to ABL flows over regions with complex terrain, including both the channeling effects of terrain and mesoscale phenomena. Several recent LLNL projects have focused on improving LES modeling for wind power applications.

Multiscale Atmospheric Flow Simulation

While mesoscale and LES models each require inflow boundary conditions, forcing of LES is trickier, as it should contain both mesoscale and turbulence information, each of which possesses significant spatial and temporal variability, which is difficult to measure and simulate. Due to these difficulties, LES have historically used idealized inflow boundary conditions. For many fundamental turbulence studies, such idealizations are applicable; however, for simulations over regions of complex terrain for which topography or mesoscale influences are important, such idealizations are problematic.

Atmospheric models that support grid nesting can provide more accurate inflow boundary conditions for LES by nesting fine-resolution LES domains within coarser-resolution mesoscale domains. Such nesting is commonly employed within regional-scale models to improve local flow prediction. Extension of grid nesting to LES scales is an active area of research at LLNL. Such multiscale atmospheric simulations including LES will benefit many facets of wind-power production, including improved understanding of physical processes, improved site characterization, and improved inflow boundary conditions for higher-resolution, turbine-resolving CFD models used in turbine design.

Turbine-Resolving CFD

LLNL is developing a turbine-resolving CFD model using overlapping grids and high-order numerics, which will permit simulation of turbine–airflow interactions of unprecedented fidelity that could greatly benefit turbine design.

Grid Integration

LLNL is collaborating with control room operators to provide quantitative situational awareness of wind conditions and energy forecasts for their native operating environments (either EMS integrated wind forecasts or wind performance/system indicators) to optimize overall grid reliability and system operations. To this end, LLNL works with wind forecasters to improve short-term energy modeling by combining *in-situ* data with remotely sensed inflow and outflow monitoring networks. Simultaneously, through direct interaction with the operators, LLNL is developing a set of indicators specifically tailored to control room operations. These activities together play a role in informing the design of an interface environment for operators nation-wide.

1.2 Renewable Energy System Data Analysis for Improved Performance and Control

LLNL has a long history of success in the analysis of massive complex data sets arising from scientific simulations, observations, and experiments. In particular, over the last decade, the Sapphire data mining project (http://computation.llnl.gov/casc/sapphire) has analyzed data from problems in various domains, ranging from plasma fusion experiments to astronomy and computer simulations of turbulence in fluid mixing. Two projects at LLNL leverage and enhance the techniques developed in the Sapphire project and are related to the analyzing data from the power grid and renewable sources of energy:

WindSENSE for control room integration. This project, started in October 2008, is funded by the Renewable Systems Interconnection program under Wind and Hydro Technologies program in EERE. The effort is motivated by our need to understand wind resources better to manage their increased contribution to the grid. We consider the problem from the viewpoint of the control room operator. Our interviews with operators at Southern California Edison (SCE), Bonneville Power Administration (BPA), and California Independent System Operator (CaISO), have indicated that operators would like 1) more accurate wind power generation forecasts on which to base the amount they should schedule and 2) additional information they can exploit when the forecasts do not match the actual generation. To achieve this, WindSENSE has two areas of focus:

- **Analysis of existing data for improved scheduling.** Working with recent data from BPA and SCE, we are trying to improve our understanding of extreme events, such as ramps and the large mismatch between the forecast and actual generation. Our early work has focused on defining ramp events and the understanding that can be gained by simple statistical analysis of these events. For example, we have shown that such analysis can help us to understand if ramps occur more frequently during certain months or certain times of the day, if negative ramps are as frequent as positive ramps, and if the different definitions change the severity and frequency of events identified in the data. Our on-going work focuses on identifying weather conditions that are associated with these extreme events. This will enable the schedulers to plan for days when extreme events are likely and when they will need additional backup generation to balance ramp events. Our planned future work includes identifying patterns in the data that can provide the schedulers some guidance on the wind power generation pattern for the day (for example, a rise in generation from early evening to midnight, followed by a gradual decrease in the early morning hours, or a rise in the early evening, followed by nearly flat generation until mid-morning, followed by a decline). This work will provide the schedulers additional information they can exploit for managing wind resources.
- **Observation targeting for improved forecasting.** This work, being done in collaboration with AWS Truewind, identifies the locations and types of observations that can most improve short-term and extreme-event forecasts. The wind generation forecasts used by utilities, such as SCE, are based on computer simulations, which are driven by observations assimilated into the time progression of the simulation. One finding shows that observations of certain variables at certain locations have more value than others in reducing the forecast error for the variable of interest, at the location of interest, for the appropriate look-ahead period. We are using an Ensemble Sensitivity Analysis approach to identify the locations and variables that will improve generation forecasts. Though much of the work in this task is being done by AWS Truewind, this problem can also be considered as a sensor-placement problem that can be solved by applying data-mining techniques to the simulation data generated by the ensembles. Funding permitting, we plan to use these analysis techniques to provide additional insights into observation targeting and provide validation of the results obtained by AWS Truewind.

Real Time Analysis of Streaming Data from Sensors. This new project, started in September 2009, focuses on developing mathematical algorithms for the analysis of peta-scale data generated by sensors monitoring complex systems, such as the power grid or physics experiments. This effort is funded by the Applied Mathematics program under DOE OASCR. The project has three main goals: (i) identify in real time, transition of the system to different operating regimes; (ii) predict in real time, anomalies or off-normal events; and (iii) extract, in near-real time, periods of interesting behavior occurring during normal operation. One of the data sets used in this project is the power grid (and other related) data used in the WindSENSE effort, complemented by additional data on the system from CaISO. The techniques being developed for the real-time prediction of anomalies and off-normal events will be of great interest in the context of the power grid.

Relevant publications

E. Natenberg, J. Zack, S. Young, J. Manobianco, and C. Kamath, "A New Approach Using Targeted Observations to Improve Short-Term Wind Power Forecasts, "WindPower 2010, Dallas, May 2010, submitted.

C. Kamath, "Understanding wind ramp events through analysis of historical data," IEEE PES Transmission and Distribution Conference, New Orleans, April 2010, submitted.

E. J. Natenberg, J. Zack, S. Young, J. Manobianco, R. Torn, and C. Kamath, "Application of Ensemble Sensitivity Analysis to Observational Targeting for Wind Power Forecasting," AMS Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, Atlanta, January 2010, accepted.

1.3 Energy System Modeling and Analysis

LLNL has developed the META•Net modeling system to better understand the functioning and long-term growth of energy systems, particularly as technologies and policies change over time. This framework has been applied to the analysis of emissions and technologies in China, the impact of carbon taxes on the energy system of Japan, and high renewable penetration and electric vehicles in the U.S.

High Time-Resolution Energy System Modeling

LLNL has recognized the need to better understand the long-term penetration and the system-wide effects of intermittent electric generation resources and energy storage. We have extended the META•Net modeling framework to model the behavior of an electric system hour-by-hour, accounting for the intermittent generation of wind and solar generators. This approach correctly captures the correlation between intermittent generation and system loads, and finds the economically optimal structure and operation of the electric generation system. We have used this modeling framework to study the penetration of intermittents and changes in the system wide value of intermittents as they penetrate. We have also used this approach to assess the impact of time resolution on the results of energy system models.

The high time-resolution modeling maintains the chronological relationship between loads and generation so that it can also model the operation and optimal sizing of energy storage devices and their interaction with the rest of the system. We have used the META•Net modeling system and other techniques to assess the impacts of energy storage on energy system structure and operations. We have used this modeling framework to assess the role of renewable resources in rural areas of Japan and in the Western U.S.

Energy system investments and operation under uncertainty

Ultimately the proposed studies of renewable energy technologies and interconnections should lead to investments in energy production facilities and transmission lines. The decisions as to which technologies to invest in, where to place them, and how to connect them to each other and load centers is complicated by the fact that we are uncertain about the scenarios of future load growth, hydro availability, patterns of loads, introduction of other technologies (e.g., demand response and electric vehicles), and future technology developments. Further, the value of investments in new technologies, particularly renewable technologies, depends on how they are operated over a specified period of time. Storage systems and hydro-electric systems must be operated under considerable uncertainty about the events occurring days or months into the future.

Existing models of energy investments tend to find a set of optimal investment paths, one for each future scenario, rather than a single investment that considers the range of possible future scenarios. To more accurately analyze investments impacted by uncertain future scenarios requires an impractically large computational effort. Our research partners at Princeton University have developed a set of procedures that solves the problem through a series of approximations termed "approximate dynamic programming" (Powell, 2007).

Researchers at Princeton have applied this approach to a number of operations issues in energy systems such as equipment replacement (Enders et al, 2009a, 2009b), emission abatement technology selection (Ryzhov and Powell, 2009), energy storage operations (Nascimento and Powell, 2009) and (Kim, 2009), and energy technology R&D decisions (Hannah et al, 2008).

LLNL has been working with Princeton to develop an analysis framework for large-scale energy systems that addresses uncertainty in a logical and usable fashion. A prototype model is called the *Stochastic Multi-scale Model for the Analysis of Energy Resources, Technology and Policy (SMART).* Initial tests have demonstrated its ability to solve inter-annual operational decisions and investment decisions under uncertainty.

References

W. B. Powell, 2007, Approximate Dynamic Programming: Solving the curses of dimensionality, John Wiley and Sons, New York

L. Hannah, W. B. Powell, and J. Stewart, 2008, "One-Stage R&D Portfolio Optimization with an Application to Solid Oxide Fuel Cells," Energy Systems Journal (under review). http://www.castlelab.princeton.edu/Papers/HannahPowell_SOFC_Oct272008.pdf

Enders, J., W. B. Powell, D. Egan, 2009a, "A Dynamic Model for the Failure Replacement of Aging High-Voltage Transformers," Energy Systems Journal (to appear). http://www.castlelab.princeton.edu/Papers/Enders-MultiPeriodTransformer_Dec2009.pdf

Ryzhov, I., W. B. Powell, 2009, "A Monte-Carlo Knowledge Gradient Method for Learning Abatement Potential of Emissions Reduction Technologies,", Winter Simulation Conference, 2009 (to appear). http://www.castlelab.princeton.edu/Papers/MC_conference.pdf

Enders, J., W. B. Powell and D. Egan, 2009b "A Two-Stage Stochastic Program for the Allocation of High-Voltage Transformer Spares in the Electric Grid," Handbook of Wind Power Systems (under review).

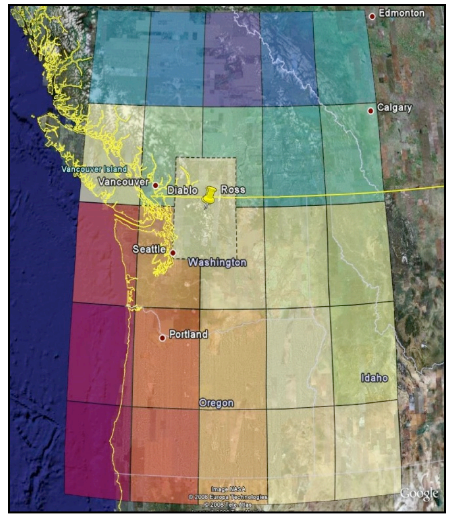
Kim, J. H., 2009, "Optimal Energy Commitments with Storage and Intermittent Supply", Operations Research (under review). http://www.castlelab.princeton.edu/Papers/Markovian_Wind_StorageSept062009.pdf

Nascimento, J., W.B. Powell, 2009, "An Optimal Approximate Dynamic Programming Algorithm for the Energy Dispatch Problem with Grid-Level Storage," SIAM J. Control and Optimization (under review). http://www.castlelab.princeton.edu/Papers/Nascimento-Powell-EnergyStorageSept0720092009.pdf

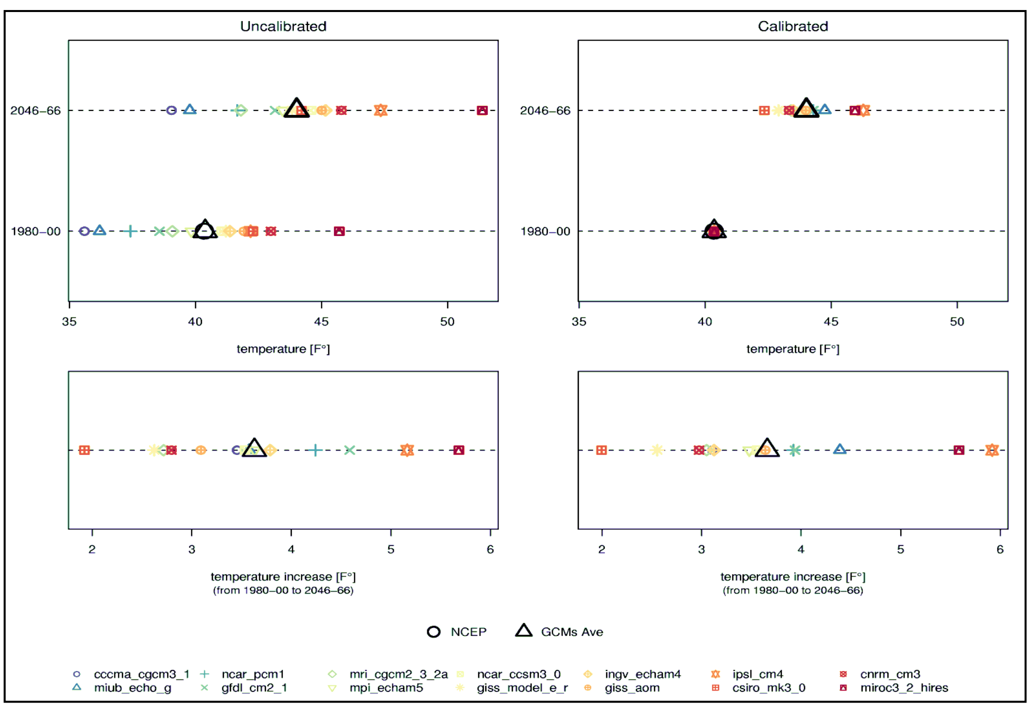
Lamont, A., 1998, *Analysis of market penetration scenarios of clean coal technologies in China using the LLNL China energy Model*, Lawrence Livermore National Laboratory, UCRL-ID-131690, August,

1.4 Downscaling Climate Global Circulation Models for Energy Analysis

LLNL has demonstrated techniques for downscaling climate global circulation models (GCMs) to spatial resolutions appropriate to analyze impacts to the energy and other sectors. This work has been done for the Department of Energy and the National Intelligence Council. The approach used includes analyzing historical data from the sites of interest and comparing it to GCMs over the same historical period. Data of interest includes precipitation quantity and type, air temperatures and air pressure.



(left) The area shown in this photo of Ross Dam in Washington State, represents the cell size of a typical GCM. (right) The area enclosed in the dotted line shows the location of the Diablo and the Ross dams within Washington State. Using site-specific historical information, we were able to downscale multiple climate models to estimate changes in temperatures at 2-meter elevation within the specific watershed.



Changes in average temperature from the 1980-00 period to the 2046-66 period as projected by 14 GCMs. (left) Uncalibrated GCM projections. (right) GCM projections calibrated to match the mean and variance of the 1980-00 NCEP2 historical data.

Downscaling is needed to answer a number of questions in the energy community:

- Precipitation changes at a watershed.
- Changes in frequency of heavy precipitation.
- Changes in the length of dry/wet spells.
- Changes in average day/night temperature in an area.
- Changes in the length and frequency of heat/cold waves.
- Changes in frequency of extreme temperatures.
- Air Pressure to estimate changes in wind speeds

LLNL applies its downscaling techniques to extract the variables of interest to energy modelers. One of the strengths of our team is the ability to be co-located with climate and energy modelers as well as the PCMDI climate model data archive at LLNL.

1.5 Critical Infrastructure Analysis

LLNL has supported the DOE and the Department of Homeland Security in the area of critical infrastructure analysis since 1996. LLNL has analyzed critical infrastructure vulnerability and risk in all 18 sectors, including electricity, oil, gas, water, and chemical. LLNL has developed a particular focus in SCADA security and the affects of "off-normal" conditions on overall grid performance, stability, and security. Our assessments have informed strategic decisions in government and industry for both planning and design of future energy systems. In addition to vulnerability and risk assessments, we have performed red-teaming and trade-off analyses in evaluating various design and/or mitigation strategies.

1.6 Cyber Security

LLNL's cyber security program has been applied to many areas throughout the U.S., including the energy sector. The Information Operations and Analytics Program (IOAP) at LLNL is responsible for research, applied development and analysis in the areas of Cyber Security, Computer Network Exploitation (CNE), and advanced knowledge management systems.

1.7 High Performance Computing and Simulation

Over the past several decades, LLNL has been a leader in the field of high performance computing. The Livermore Computer (LC) Center is the home of a first class supercomputing infrastructure supporting the computational requirements of LLNL scientists and engineers, and users from remote facilities. Currently, LC houses several powerful supercomputers, include a 212,992-processor IBM BlueGene/L, 147456-processor IBM BlueGene/P, and 9216-, 2304-, and 4096- processor clusters. In addition, LLNL has been a technology leader in this field, driving the first development of production-class cluster computers and the IBM/BlueGene series, Lustre file system, system management technologies such as SLURM, and leading research and development of debugging and performance analysis tools. It should be noted that over the past ten years, LLNL supercomputers have ranked as the top performing systems in the world. This was achieved through partnership with industry, developing computing technologies and architectures, and conducting leading-edge research.

Since the inception of the LLNL, simulation represented a key tool in modeling and understanding systems. Currently, the Laboratory is developing and supporting numerous users via engineering and science code. A few examples of the engineering codes include electromagnetic solver EMSolve, shock physics / denotation code ALE3D, structural mechanics/dynamics code ParaDYN (successor of the well-known DYNA code). These codes are used in a wide variety of national security mission areas, such as rail gun design for the Navy and studying the effects of blast on vehicles and ships. In addition, the Laboratory develops and supports science codes used for materials science, thermo-chemistry calculations, and systems analysis. The Laboratory has a large staff (over 400) that are developing and conducting research to advance a wide variety of scalable and robust simulation and data analysis software for the Laboratory's various mission areas.

Selected Publications

Yao, Y., Edmunds, T., Papageorgiou, D., and Alvarez, R. (2003) *Optimal Resource Allocation in Electrical Network Defense*, LLNL UCRL-TR-201959.

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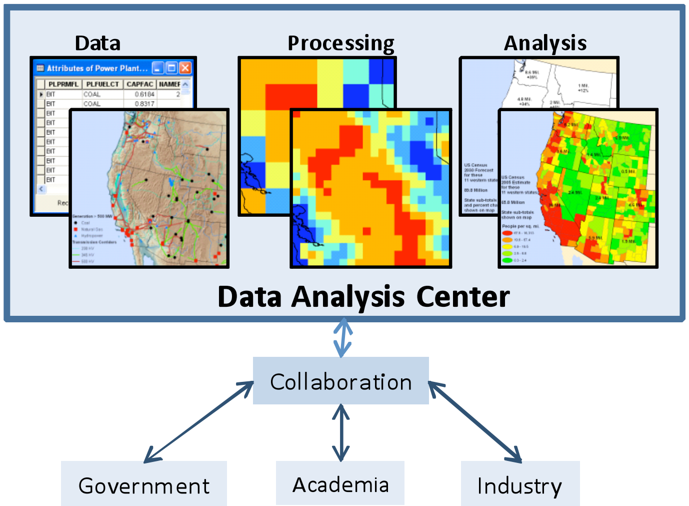
1.8 Energy Data Center

The Energy Data Sharing, Processing, and Analysis Center leverages LLNL's expertise in geographic information systems (GIS), databases, and tool development to enhance energy system modeling and analysis. We maintain a repository of tabular and spatial data for the Western Region based on public, commercial, and proprietary energy company data sources. We plan to expand the spatial coverage to support national and international energy analysis. We have prototyped data analysis capabilities that can transform, rescale, and sample this energy data repository to support energy modelers. We have also developed tools to analyze and visualize model inputs and results using graphs, tables, and maps. We currently support LLNL's energy modelers, but we will develop an online process that provides secure external partner access to the data, models, and analysis. The Data Analysis Center reduces the cost of maintaining distributed and ad hoc data energy dataset and insures that the validated data are available to all partners which enables the highest quality energy system analysis.



The Energy Data Center manages and produces large-scale data sets for analysis.

1.9 Key Organizations

LLNL has extensive capability and expertise in high-performance computing and systems and decision sciences (see organization charts below from the Center for Applied Scientific Computing and Systems and Decision Sciences). These capabilities will be used to support R&D in alternative electricity supply.

Organization Chart for
Center for Applied Scientific Computing
Lori A. Diachin, Director (Acting)
Xabier Garaizar, Deputy Director (Acting)
Clea Marples, CASC Administrator
Tracy Baldwin, CASC Resource Analyst
Shilo Smith, Division Secretary
Karen Bathrick, Support Secretary
Anita Cocilova, Support Secretary

Computational Mathematics
Ulrike Yang (Acting)
Allison Baker
Jeffrey Banks
Kyle Chand
Veselin Dobrev
Rob Falgout
Bill Henshaw
Van Henson
Tzanio Kolev
Steven Lee
Anders Petersson
Bjorn Sjogreen
Panayot Vassilevski

Computational Physics
Louis Howell
Bill Bateson
Aaron Fisher
Stephen Guzik
Gary Kerbel
Mike Lambert
Nathan Masters
Jose Milovich
Douglas Peters
Kambiz Salari
Dan Shumaker
Mike Singer
Charles Tong
Ping Wang

Computer Science
Tom Epperly (Acting)
Greg Bronevetsky
Bor Chan
Bronis de Supinski
Dietmar Ebner
Todd Gamblin
David Jefferson
James Leek
Chunhua Liao
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Brian Miller
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Dan Quinlan
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Celeste Matarazzo
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Andy Yoo

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Robert Anderson
Peter Brown
Britton Chang
Milo Dorr
Erik Draeger
Noah Elliott
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Brian Gunney
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Debbie May, IOAP/Z
Jeff Latkowski, LIFE/NIF
John Nitao, Applied Math
Mike O'Brien, MPC&A
David Paglieroni, JIEDDO
Doug Poland, IOAP/Z
Bill Smith, Bio-Fuels
Jeff Stewart, Energy/Climate
Richard Wheeler, Homeland Security

Organization Chart for Systems & Decision Sciences
Bill Hanley - Section Leader
Jim Gansemer - Deputy Section Leader
Tom Edmunds - Chief Scientist
Carrie Wilson - Adm. Assistant

Consultant
Steve Arnon, Dept PH, CA.
Michael Goodchild, UCSB
Dan Kammen, UCB
Herbie Lee, UCSC
Joan Ogden, UCD
Warren Powell, Princeton Univ.

Simulation & Decision Sciences
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Matt Dombroski
Souheil Ezzedine
Dan Faissol
Keith Huffer
Katie Lundquist
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Carol Meyers
Sarah Powers
Robert Shectman
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Yiming Yao
Jill Watz

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Farid Dowla
Chuck Grant
Siddharth Manay
Sailes Sengupta
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Paul Kidwell
Milovan Krnjajic)
Ana Kupresanin
Alan Lamont
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John Lathrop
Faranak Nekoogar
Steve Porter
Alan Sicherman
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David Aldis
Debbie Andrews
Phil Brady
Gregg Brumburgh
John Crandley
John Dolaghan
Ron Durling
Mary Foltz
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Glenn May
Roger Miller
Suzanne Monaco
Jo Neuman
Jayne Tonowski

Network Exploitation
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Chris Brand
Jonathan Cam
Domingo Colon
Matt Damante
Robert Fernandes
Riki Gay
Roland Johnson
David Gutierrez

Data Analysis & Informatics
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Lance Bentley-Tammero
Kofi Boakye
Barry Chen
Gayatri Gururangan
Joyce Ho
Will Kallander
Greg Kosinovsky
Brenda Ng
Kevin Ni
Ryan Prenger
Kush Varshney

Intelligence Analytics
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Jeremy Hill
Bill Orvis
Steve Wong
Tim Voss
Chris Roblee
Kevin Snyder
Noel Tijerino

2. Project Management Qualifications

Project management is one of many core strengths of LLNL, as demonstrated by our record in managing large, high-profile projects in accordance with DOE project management procedures, delivery of research and construction projects on time and at cost to meet technical requirements.

In a given year, our portfolio of hundreds of projects is highly diverse, ranging from small developmental prototypes to congressional line-item construction projects. A sampling of high-profile projects includes the National Ignition Facility and the Terascale Facility. LLNL advocates tailoring management processes to fit each project's unique requirements, using a risk-based graded approach.

Industry best practices in project management are embraced by LLNL's matrix organizations, which provide extensive training, mentoring, and procedural support. LLNL is certified as a Registered Education Provider by the Project Management Institute, which means that has been recognized as qualified trainer of Project Management Professionals (PMP). A significant number of LLNL staff have been certified by this internationally recognized credential. Our project managers are well-versed in such fundamental skills as critical path analysis, resource loaded scheduling, scope management, and risk management.

Project management at LLNL is a skill set that is highly integrated with our numerous technical disciplines: mechanical engineering; field engineering; structural, thermal, vacuum, and fluid systems development and analysis; multi-physics and materials modeling; and cryogenics. Significant experience is also available in engineering optical and x-ray diagnostic systems and tritium process systems. Electronics engineering expertise includes development of real-time data acquisition and processing, advanced radiography, antenna modeling and high-power RF systems, and nuclear and electromagnetic radiation effects. LLNL also has considerable expertise in communications and networking, information systems vulnerability, instrumentation and integrated control systems, and signal processing applications. We have developed world-class adaptive optics, pulse-power, and electro-optics systems. All engineering disciplines incorporate the fundamental elements of project management expertise and training.

LLNL conducts activities to support the mission needs and national security requirements of the DOE and the National Nuclear Security Administration (NNSA). The Office of Engineering and Construction Management within DOE oversees line-item construction projects at DOE/NNSA sites. As a DOE/NNSA laboratory, LLNL follows the requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets, and its accompanying guidance manual, which delineates Earned Value requirements. Capital Asset projects at LLNL are executed under the guidance of DOE Order 413.3, which defines Critical Decision points representing "exit points from one phase of the project and entry to the succeeding phase" in the project.

For the hundreds of smaller projects that do not require the level of documentation and control of DOE Order 413.3, LLNL applies the same project management principals, but with a graded level of formality.

2.1 Experience in managing collaborative projects

Analyses and planning must be developed and performed in a transparent and collaborative manner, and the study processes must be open to participation by state and federal officials, representatives from independent system operators (ISOs) and regional transmission organizations (RTOs), utilities, and relevant stakeholder bodies or non-governmental organizations (NGOs), including appropriate entities in Canada and Mexico. To the extent possible, consensus is achieved among stakeholders on key issues.

As a multidisciplinary laboratory, LLNL has significant experience collaborating with industry and other institutions both at a national and international level. For example, the EUV Lithography Program was a highly integrated consortium of laboratory and industrial partners from the semiconductor industry developing lithography techniques for the mass production of integrated computer circuits. The development of PERIGRINE, a system to determine precise radiation doses for cancer patients, involved a major collaboration among LLNL, University of California San Francisco, the National Cancer Institute, and NOMOS Corporation. LLNL provided significant physics and engineering expertise to the B Factory at Stanford Linear Accelerator (SLAC) in collaborations with SLAC and Lawrence Berkeley National Laboratory to develop the B_Factory's accelerator. LLNL also had a lead role in developing the PHENIX detector at Brookhaven National Laboratory, which was a multi-institutional, multinational collaboration. The numerous joint projects in which LLNL either led or participated range from the Human Genome Project to the Advanced Simulations and Computing Program to user facilities like the Center for Accelerator Mass Spectroscopy. Internationally, LLNL played a key role in collaborating with scientists from the new Russian Federation to secure fissionable material associated with their weapons program.

2.2 Management approach

Project managers for transmission analysis and planning projects will be expected to assess the project risks necessary to manage stakeholder expectations and to assure the accomplishment of project objectives through the tailored application of project planning and controls. The extent of this effort is determined by the need to thoroughly identify, characterize, and manage failure modes at the level of risk tolerance approved by project stakeholders. The output of this assessment is a Risk Authorization Level (RAL) and the determination of required project controls. Project managers are expected to obtain concurrence on their risk assessment from their line management. A risk assessment tool is used to facilitate this grading process.

LLNL projects undergo project management reviews based on the level of project risk during the planning phase and at appropriate stages of the project. At project initiation, the project sponsor and LLNL will establish the scope and frequency of project management reviews for the duration of the project. The project manager and key stakeholders will determine appropriate times for reviews.

An Integrated Project Schedule (IPS) will be developed to provide the logical sequencing of activities, and their significant interdependencies required to accomplish the scope. The IPS provides horizontal and vertical traceability and interdependencies. Key milestones are decision points and are included as constraints. The IPS may also be used to perform critical path analysis.

A structured and integrated approach will be followed to complete all tasks, using a work breakdown structure (WBS), organizational breakdown structure (OBS), responsibility assignment matrix (RAM), and control accounts. These tools provide the foundation of the project management plan.

3. Personnel and Laboratory Qualifications

John Grosh

John Grosh serves as the Acting Department Head for the Computing Applications and Research Department, where he manages over 400 computer scientists, engineers, and mathematicians supporting development and research of software technologies and applications codes for LLNL's programs. Mr. Grosh's previous position was the Director for the Center for Scientific Computing (CASC), where he led mission-focused research in computer science, applied mathematics, data analytics, and computational science. From 2000 to 2006, he served in the Office of the Director of Defense Research and Engineering where he initiated and oversaw R&D programs in high performance computing, cyber security, and embedded software. In addition, he co-chaired the 2003-2004 White House task force on high-end computing, chaired the Interagency Working Group in High-End Computing Research, led and participated in red teams and technology readiness assessments for major DoD acquisition programs, and formulated government policy in export controls high performance computing and microprocessors. Prior to joining the Office of the Secretary of Defense, worked at the Army Research Laboratory as a program manager in scalable applications software and tools for high performance computers, leading scientific visualization research, conducting research in molecular dynamics for detonation physics, and designing and testing of novel tank ammunition concepts. Mr. Grosh has an M.S. in Mathematics from the University of Delaware and a B.S. in Chemical Engineering from The Pennsylvania State University.

Nalu B. Kaahaaina

Education

M.S. Stanford University - Mechanical Engineering
B.S. Stanford University - Mechanical Engineering
B.A. Stanford University - Science, Technology, and Society

Experience

11/06 – Present

Low-Carbon Energy Program Leader, Energy & Environmental Security, Lawrence Livermore National Laboratory

Responsible for developing sponsors for energy research. Program spans geothermal, wind power, hydrogen storage, advanced engines/combustion, electrical grid operations, energy-water nexus, and energy-economic analysis. Engage technical problems stemming from energy access/cost, resource/infrastructure protection, and national security. Client base includes numerous public entities and private firms. Also direct internal funding for next-generation research.

9/02 – 10/06

Deputy Director, Advanced Energy Systems Laboratory, Mechanical Engineering Department, Stanford University

Lead research on innovative energy conversion processes, including technical and managerial responsibilities. Technical topics include advanced combustion, hydrogen fuel, fuel cells, and emissions. Research sponsors include DOE, Robert Bosch Corp., General Motors, and The Stanford Global Climate and Energy Project.

Chandrika Kamath

Center for Applied Scientific Computing
Lawrence Livermore National Laboratory
Livermore, CA 94551
http://people.llnl.gov/kamath2

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Fax: (925) 423-2993
E-mail:kamath2@llnl.gov

Research Interests

• Practical applications of data analysis	• Data mining
• Signal, image, and video processing	• Pattern recognition and machine learning
• Statistical analysis	• High-performance scalable computing

Education

Ph.D.	Computer Science, University of Illinois at Urbana-Champaign, 1986
M.S.	Computer Science, University of Illinois at Urbana-Champaign, 1984
B. Tech.	Electrical Engineering, Indian Institute of Technology, Bombay, India, 1981

Professional Experience

5/97 – present	Computer Scientist/Project Lead, CASC, LLNL
10/98 – 9/07	Project Leader, Sapphire scientific data mining project
1/96–4/97	Consulting Software Engineer, Digital Equipment Corporation
12/86–12/95	Principal Software Engineer, Digital Equipment Corporation
8/81–8/84	Research Assistant, Center for Supercomputing Research and Development, UIUC

Selected Honors and Organizations

- Steering Committee Chair, SIAM International Conference on Data Mining, 2007-present
- Editor-in-Chief, Wiley journal on Statistical Analysis and Data Mining, 2006-present.

- 2006 R&D 100 award for the Sapphire Scientific Data Mining Software
- US Patents 6675162 (Jan 6, 2004), 6,859,804 (Feb 22, 2005), 6,879,729 (April 12, 2005), 6,938,049 (Aug. 30, 2005), 7,007,035 (February 28, 2006), and 7,062,504 (June 13, 2006). One patent pending.
- Conference co-chair, SIAM International Conference on Data Mining, 2004-2005.
- Program co-chair, Third SIAM International Conference on Data Mining, San Francisco, May 2003.
- Member, NRC Panel, NASA's Computing, Information, and Communications Technology, 2002-03
- Lead organizer, IPAM program on Mathematical Challenges in Mining Scientific Data, UCLA, 2002
- Organizer, First through Ninth Workshops on Mining Scientific Datasets, 1999 – 2006.
- Member, various program committees for Data Mining Conferences, 2000-present.
- IBM Graduate Fellowship, 1984–86
- Senior member, IEEE; Member, ACM, SPIE, and SIAM

Books

C. Kamath, *Scientific Data Mining: A Practical Perspective*, SIAM, Philadelphia, PA, May 2009. ISBN 978-0-89871675-7.

R. Grossman, C. Kamath, P. Kegelmeyer, V. Kumar, and R. Namburu (eds.), *Data Mining for Scientific and Engineering Applications,* Kluwer, September 2001. ISBN 1-4020-0033-2.

Selected Recent Publications and Presentations

C. Kamath, "Understanding wind ramp events through analysis of historical data," IEEE PES Transmission and Distribution conference, New Orleans, April 2010.

E. Natenberg, J. Zack, S. Young, J. Manobianco, R. Torn, C. Kamath, "Application of ensemble sensitivity analysis to observational targeting for wind power forecasting,", AMS Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, Atlanta, January 2010.

C. Kamath, A. Gezahegne, and P. L Miller, "Identification of coherent structures in three-dimensional simulations of a fluid-mix problem," International Journal of Image and Graphics, Volume 9, issue 3, pp. 389-410, July 2009.

C. Kamath, N. Wale, G. Karypis, G. Pandey, V. Kumar, K. Rajan, N. F. Samatova, P. Breimyer, G. Kora, C. Pan,S.Yoginath, "Scientific Data Analysis", book chapter in "Scientific Data Management", A. Shoshani and D. Rotem, editors, CRC Press/Taylor and Francis books, 2009, to appear.

C. Kamath, "Sapphire: Experiences in Scientific Data Mining,", SciDAC 2008, Journal of Physics Conference Series 125, 012094, July 2008.

C. Kamath and P. L. Miller, "Image Analysis for Validation of Simulations of a Fluid Mix Problem," IEEE International Conference on Image Processing, Volume III, pages 525-528, San Antonio, September 2007.

A. Bagherjeiran, N. S. Love, C. Kamath, "Estimating Missing Features to Improve Multimedia Retrieval," IEEE International Conference on Image Processing, Vol. II, pages 233-236, September 2007.

A. Bagherjeiran and C. Kamath, "Graph-based methods for orbit classification", Proceedings, SIAM International conference on Data Mining, April. 2006.

E. Cantú-Paz and C. Kamath, “An empirical comparison of combinations of evolutionary algorithms and neural networks for classification problems,” IEEE Trans on Systems, Man, and Cybernetics-Part B, Volume 35, No. 5, October 2005, pp. 915-927.

S.-C. Cheung and C. Kamath, “Robust background subtraction with foreground validation for urban traffic video,” Eurasip Journal on Applied Signal Processing, Volume 14, August 2005, pp. 2330-2340.

C. Kamath, E. Cantú-Paz, S. Cheung, I. K. Fodor, N. Tang, “Experiences in mining data from computer simulations,” chapter in New Generation of Data Mining Applications, M. Kantardzic and J. Zurada (eds.), pp. 211-232, IEEE Press, 2005.

Fodor, I. K. and C. Kamath, “Denoising through Wavelet Shrinkage: An Empirical Study”, SPIE Journal on Electronic Imaging, Volume 12, No. 1, pp 151-160, January 2003.

Brian Lopez

Mr. Lopez is a computer scientist at Lawrence Livermore National Laboratory (LLNL) where he has led the research, development and delivery of technology, process and strategy for a wide variety of commercial and government sponsors since 1990. For the past ten years he has been leading in-depth assessments of threat, vulnerability and consequence across 28 U.S. states – including the 2002 Winter Olympics, California energy crisis, and 9/11 response.

His previous work was in the areas of knowledge management, electronic commerce, cryptography & digital signatures, workflow, PbE-based translators, nuclear material tracking and NTK-based secure data exchange. Mr. Lopez has consulted on technology, business practices, and strategic management for organizations throughout the U.S. and abroad. He has designed and led the development and delivery of secure, large-scale ($1B+ transaction flow) systems. He lectures occasionally and has taught courses for the UC-Berkeley in both technology and strategic management. His work has been licensed to two major corporations and six start-ups. Mr. Lopez received bachelors in Computer Science and Rhetoric from the University of Minnesota and did graduate work in Computer Science at Cambridge University in England.

Strengths: Creativity – Strategy – Execution **Clearance Level:** DOE Q Sigmas SCI

1998-present Founder / Program Leader Vulnerability and Risk Assessment Program (VRAP)

VRAP provides in-depth, multi-disciplinary assessments of threat, vulnerability, and consequence. Past projects include work in 28 states and internationally including the 2002 Winter Olympics, CA Energy Crisis, and 9/11 response. Program provides analysis at a variety of scales (facility, infrastructure, city, region, state, multi-state, nation) and has purpose-built fixed and mobile capabilities to support field assessments. Teams specialize in critical asset identification, threat analysis, cyber and physical security, penetration, OPSEC, interdependencies, policies and procedures, consequence analysis, risk characterization & mitigation, and methodology development. Mr. Lopez has extensive experience leading diverse teams into complex public/private environments to develop actionable solutions which are credible with all stakeholder groups.

Alan D. Lamont

Present Position
Engineer, National Security Engineering Division
Lawrence Livermore National Laboratory
Livermore, CA 94550

Education
Ph.D. Stanford University, Engineering-Economic Systems, 1983

M.S. Stanford University, Engineering-Economic Systems, 1977

M.S. Stanford University, Civil Engineering, 1970

B.S. Stanford University, Civil Engineering, 1970

Employment History
1987 - present Lawrence Livermore National Laboratory, Livermore, CA
- Engineer, Statistics and Economics Group, National Security Engineering Division

Experience
Energy systems modeling and analysis: Developed and applied modeling techniques for design and analysis of energy systems with intermittent resources and storage. Developed and applied the META•Net software system for building and running large energy economics models. Managed the development of economic equilibrium models of the US energy system, U.S. uranium markets, and the Chinese energy system. Conducted economic analysis of the need for cogeneration facilities in California. Conducted analysis of the future costs and availability of coal for electric generation in the Pacific Northwest.

Decision analysis and probability modeling: Managed decision analysis studies applied to various DOE projects. Developed analytical tools for designing monitoring programs for underground storage tanks and evaluating and comparing research proposals. Applied probabilistic modeling to failure of pipelines in permafrost, dam failures, risks of toxic spills, estimation of uranium resources, and risks due to oil spills. Managed the design and development of data bases, simulation models and expert systems for hazardous waste management.

Teaching and course preparation: Developed and presented courses in decision analysis and probability modeling. Developed and managed a training course for energy industry executives for the National Defense Executive Reserve which presents the laws and procedures under which the federal government can manage the energy industry during national emergencies.

General Research Interests
Economic modeling of energy systems, decision analysis, probabilistic modeling, integration of complex systems models

Professional Affiliations
Member, the Institute of Management Science

Affiliate of the Energy and Resources Group, University of California, Berkeley

Tau Beta Pi

Publications

Journal articles, book chapter
“Assessing the long-term system value of intermittent electric generation technologies”, *Energy Economics*, Vol. 30, pg 1208-1231, 2008

“Design for renewable energy systems with application to rural areas in Japan” *Energy Policy*, Vol. 33, pages 209-219. with T. Nakata, K. Kubo, also available as LLNL report at http://www-r.llnl.gov/tid/lof/documents/pdf/243584.pdf

“Carbonless Transportation and Energy Storage in Future Energy Systems”, in *Innovative strategies for CO2 stabilization,* Robert G. Watts, ed., Cambridge University Press, 2001, with G. Berry, also available as LLNL report at : http://www.llnl.gov/tid/lof/documents/pdf/239026.pdf

“Analysis of the Impacts of Carbon Taxes on Energy Systems in Japan”, *Energy Policy*, Volume 29, Issue 2, January 2001, Pages 159-166 with T. Nakata

“Modeling the Impacts of a Market for Emissions Permits” *International Journal of Environmentally Conscious Design and Manufacturing*, Vol. 5, Num. 3-4, 1996

"A Probabilistic Approach to the Assessment of Uranium Resources", *Mathematical Geology,* Vol. 13, No. 6, 1981, with K. Golabi

Reports
Impact of Time Resolution on the Projected Rates of System Penetration by Intermittent Generation Technologies, Lawrence Livermore National Laboratory, 2006, UCRL-TR-222954, with T. Wu

Assessing the long-term system value of intermittent electric generation technologies, Lawrence Livermore National Laboratory, 2006, UCRL-TR-215091, Submitted to *Energy Economics*

Jeffrey D. Mirocha

Research Interests

- Atmospheric turbulence and boundary layer modeling and measurement
- Development and leadership of research efforts to improve modeling of atmospheric boundary layer processes, including:

  - Large-eddy simulation and turbulence subfilter model development
  - Multi-scale flow simulations (mesoscale to LES)
  - Developing improved physics for the Weather Research and Forecasting model
  - Coupled atmosphere-subsurface water cycle modeling
  - Building-resolving, urban-scale flow simulation
- Atmospheric transport and dispersion
- Fundamental studies and applications, particularly wind energy

Education

University of Colorado at Boulder, Boulder CO	Astrophysical, Planetary, and Atmospheric Science	Ph.D. 2005
University of Colorado at Boulder, Boulder CO	Astrophysical, Planetary, and Atmospheric Science	M.S. 2000
Arizona State University,	Geography	B.S. 1998
Tempe, AZ	Mathematics	B.A. 1998

Professional Experience

01/2007-Present Physicist, Lawrence Livermore National Laboratory, Livermore, CA

- Define and lead projects involving atmospheric turbulence modeling in a variety of applications, including atmospheric dispersion and wind energy
- Develop a multi-scale flow simulation capability using the Weather Research and Forecasting (WRF) model
- Enable coupling of WRF with a subsurface flow model (PARFLOW)
- Implemented and evaluated new turbulence subfilter models in the WRF model for improved Large-eddy simulation
- Implemented improved physics parameterizations into a building-resolving finite element computational fluid dynamics model (FEM3MP)
- Run massively parallel jobs on supercomputing clusters
- Recruit and supervise postdoctoral researchers
- Prepare and present proposals for internal (LDRD) and external (DOE) funding
- Interact with external sponsors (DOE, Industry)

10/2005-12/2007 Postdoctoral Researcher, Lawrence Livermore National Laboratory, Livermore, CA

- Implemented and evaluated new subfilter stress models in the Weather Research and Forecasting model (WRF)

- Analyzed atmospheric turbulence data to quantify the role of low-level jets in turbulence dynamics and dispersion during the Joint URBAN 2003 field experiment
- Investigated tracer dispersion in New York City using a building-resolving computational fluid dynamics model
- Conducted long-term large-eddy simulations of stable boundary layers to quantify effects of subsidence

Spring, 2005 Teaching Assistant, University of Colorado, Boulder, CO

- Taught two undergraduate atmospheric science laboratories at the University of Colorado at Boulder

Principal Investigator Experience

2009-2011 DOE Office of Energy Efficiency and Renewable Energy (EERE) "20% by 2030": Characterization of turbine inflow conditions using multi-scale atmosphere modeling.

2009-2011 LLNL Laboratory-Directed Research and Development: "Improving atmospheric flow prediction at intermediate scales"; improving representation of turbulence across multiple scales in the numerical weather predication model WRF

Peer-Reviewed Publications

1. Mirocha, J. D., and B. Kosović, 2009: A large-eddy simulation study of the influence of subsidence on the stably-stratified atmospheric boundary layer, *Bound.-Layer Meteor.,* **134**, 1-21.
2. Lundquist, J. K., and J. D. Mirocha, 2008: Interaction of nocturnal low-level jets with urban geometries as seen in Joint URBAN 2003 data. *J. Appl. Meteor. Climate.*, **47**, 44-58.
3. Mirocha, J. D., B. Kosović, and J. A. Curry, 2005: Vertical heat transfer in the lower atmosphere over the Arctic Ocean during clear-sky periods, *Bound.-Layer Meteor.,* **117**, 37-71.

In Review or Preparation

1. Mirocha, J. D., J. K. Lundquist, and B. Kosović. 2009: Implementation of a nonlinear subfilter turbulence stress model for large-eddy simulation in the Advanced Research WRF Model, Submitted to *Mon. Wea. Rev.*
2. Lundquist, J. K., J. D. Mirocha, F. K. Chow, K. A. Lundquist, and B. Kosović. 2009. Meteorological modeling for wind energy applications: model improvements and validation. In preparation for *Wind Energy.*

Technical Reports

Mirocha, J. D., J. K. Lundquist, F. K. Chow, B. Kosović. 2008: Description of new LES subfilter turbulence models implemented into WRF ARW V3.0.1, LLNL Technical Report LLNL-TR-408080.

Recent Honors and Awards

'Regional- to Urban-Scale Influences on Atmospheric Turbulence and Dispersion', J. D. Mirocha, Lundquist, J. K., Chan, S. T., Lundquist, K. A. and Chow, F. K.; voted First Place at the Lawrence Livermore National Laboratory's Energy and Environment Postdoc Poster Session, 18 May, 2006

'Vertical Heat Transfer over the Arctic Ocean', a summary of the similarly entitled talk, presented at the 16th Symposium on Boundary Layers and Turbulence, 9-13 August 2004, Portland, Maine, appeared in the Conference Notebook section of the September, 2004 issue of *Bull. Amer. Meteor. Soc.*

Warren Powell

Selected papers by Warren Powell in energy systems analysis, resource management and algorithms for optimization under uncertainty

Links below each paper will bring up the paper from the Castle Lab website, located at www.castlelab.princeton.edu. To bring up the paper, hold down the Control key and click on the link.

Energy systems analysis

J. Enders, W. B. Powell, D. Egan, "A Dynamic Model for the Failure Replacement of Aging High-Voltage Transformers," Energy Systems Journal (to appear).

http://www.castlelab.princeton.edu/Papers/Enders-MultiPeriodTransformer_Dec2009.pdf

Ryzhov, I., W. B. Powell, "A Monte-Carlo Knowledge Gradient Method for Learning Abatement Potential of Emissions Reduction Technologies,", Winter Simulation Conference, 2009 (to appear).

http://www.castlelab.princeton.edu/Papers/MC_conference.pdf

J. Enders, W. B. Powell and D. Egan, "A Two-Stage Stochastic Program for the Allocation of High-Voltage Transformer Spares in the Electric Grid," Handbook of Wind Power Systems (under review).

http://www.castlelab.princeton.edu/Papers/Enders-TwoStageMay252009.pdf

J. Nascimento, W. B. Powell, "An Optimal Approximate Dynamic Programming Algorithm for the Energy Dispatch Problem with Grid- Level Storage," SIAM J. Control and Optimization (under review).

http://www.castlelab.princeton.edu/Papers/Nascimento-Powell-EnergyStorageSept0720092009.pdf

Jae Ho Kim – Optimal Energy Commitments with Storage and Intermittent Supply, Operations Research (under review).

http://www.castlelab.princeton.edu/Papers/Markovian_Wind_StorageSept062009.pdf

Powell, W. B., George, A., A. Lamont and J. Stewart, "SMART: A Stochastic Multiscale Model for the Analysis of Energy Resources, Technology and Policy," Informs Journal on Computing (under review).

http://www.castlelab.princeton.edu/Papers/SMART_August142009.pdf

L. Hannah, W. B. Powell, and J. Stewart, "One-Stage R&D Portfolio Optimization with an Application to Solid Oxide Fuel Cells," Energy Systems Journal (under review).

http://www.castlelab.princeton.edu/Papers/HannahPowell_SOFC_Oct272008.pdf

Resource management

Marar, A. and W. B. Powell, "Capturing Incomplete Information in Resource Allocation Problems through Numerical Patterns," European Journal of Operations Research, Vol. 197, No. 1, pp. 50-58 (2009)

http://www.castlelab.princeton.edu/Papers/Marar%20Powell-Capturing%20incomplete%20iniformation%20through%20numerical%20patterns.pdf

Simao, H. P. and W. B. Powell, "Approximate Dynamic Programming for Management of High Value Spare Parts", Journal of Manufacturing Technology Management Vol. 20, No. 2, pp. 147-160 (2009).

http://www.castlelab.princeton.edu/Papers/Simao%20Powell-%20ADP%20for%20Spare%20Parts.pdf

George, A., W.B. Powell and S. Kulkarni, "Value Function Approximation Using Hierarchical Aggregation for Multiattribute Resource Management," Journal of Machine Learning Research, Vol. 9, pp. 2079-2111 (2008).

http://www.castlelab.princeton.edu/Papers/George%20Powell%20Kulkarni%20-%20Value%20function%20approx%20using%20multiple%20aggregation-JMLR_Oct022008.pdf

Nascimento, J. and W. B. Powell, "An Optimal Approximate Dynamic Programming Algorithm for the Lagged Asset Acquisition Problem," Mathematics of Operations Research, Vol. 34, No. 1, pp. 210-237 (2009).

http://www.castlelab.princeton.edu/Papers/NascimentoPowell-Optimal%20ADP%20for%20lagged%20asset%20acquisition%20problem.pdf

Marar, A. W. B. Powell and S. Kulkarni, "Combining Cost-Based and Rule-Based Knowledge in Complex Resource Allocation Problems," IIE transactions Vol. 38 (2), pp. 159-172 2006.

http://www.castlelab.princeton.edu/Papers/Marar%20Powell%20Kulkarni%20-%20Cost-based%20and%20rule-based%20patterns%20.pdf

Topaloglu, H. and W.B. Powell, "Dynamic Programming Approximations for Stochastic, Time-Staged Integer Multicommodity Flow Problems," *Informs Journal on Computing*, Vol. 18, No. 1, pp. 31-42 (2006).

http://www.castlelab.princeton.edu/Papers/Topaloglu%20Powell-DP%20approximation%20for%20stochastic,%20time-staged%20integer%20MC%20flow.pdf

Powell, W.B., J. Shapiro and H. Simao, "A Metastrategy for Dynamic Resource Management Problems based on Informational Decomposition," *Informs Journal on Computing*, Vol. 18, No. 1, pp. 43-60 (2006).

http://www.castlelab.princeton.edu/Papers/Shapiro%20Powell%20-%20Metastrategy%20for%20resource%20management%20based%20on%20inf%20decomposition.pdf

Optimization under uncertainty

Books:

W. B. Powell, Approximate Dynamic Programming: Solving the curses of dimensionality, John Wiley and Sons, New York, 2007.

http://www.castlelab.princeton.edu/adp.htm

J. Si, A. Barto, W.B. Powell and D. Wunsch (eds.), Learning and Approximate Dynamic Programming: Scaling up to the Real World, John-Wiley and Sons, New York, 2004.

Papers:

Powell, W.B., "Merging AI and OR to Solve High-Dimensional Resource Allocation Problems using Approximate Dynamic Programming" Informs Journal on Computing (to appear).

http://www.castlelab.princeton.edu/Papers/Powell_JOC-ADP_feature_May2009.pdf

P. Frazier, W. B. Powell, S. Dayanik, "The Knowledge-Gradient Policy for Correlated Rewards," Informs Journal on Computing, Vol. 21, No. 4, pp. 585-598 (2009)

http://www.castlelab.princeton.edu/Papers/Frazier_CorrelatedKnowledgeGradientJOC.pdf

Frazier, P., W. B. Powell and S. Dayanik, "A Knowledge Gradient Policy for Sequential Information Collection," SIAM J. on Control and Optimization, Vol. 47, No. 5, pp. 2410-2439 (2008).

http://www.castlelab.princeton.edu/Papers/FrazierPowellDayanik_KnowledgeGradientSICON.pdf

George, A. and W. B. Powell, "Adaptive Stepsizes for Recursive Estimation with Applications in Approximate Dynamic Programming," Machine Learning, Vol. 65, No. 1, pp. 167-198, (2006).

http://www.castlelab.princeton.edu/Papers/George%20Powell%20-%20Adaptive%20stepsizes%20for%20recursive%20estimation%20with%20applications%20to%20ADP.pdf

Jeffrey Stewart

Program leader for the Regional Energy Systems Technology Analysis Center and User Facility and the Western Region Energy Consortium.

Jeffrey Stewart created and leads both the RESTAC and Western Region Energy Modeling Consortium. RESTAC brings together multi-disciplinary teams comprised of Systems Sciences, Atmospheric Sciences, Computations, Visualization, Engineering, Material Sciences, and Mathematics. These teams bring the resources of one of DOE's largest labs to address problems related to deploying low carbon energy systems.

The Western Region Energy Consortium is a group comprised of national labs, universities and western region utilities focused on developing and applying system models appropriate for analzing reliability, economic and security concerns related to the future energy system. The consortium is designed for members to share data, models and expertise to find plausible solutions to low carbon and reliable energy.

Jeffery J. Roberts

Experience Summary:

Research scientist in mineral physics and laboratory geophysics for national laboratory with experience leading research projects and managing laboratory facilities and personnel.

Professional Skills and Areas of Expertise:

Environmental and Energy Research
Project and Program Management
Impedance Spectroscopy
Physics of Microporous Media
Defect Chemistry and Transport
Microtomographic Imaging and Visualization
Electrical Properties of Materials
Microstructural Characterization

Education

Arizona State University, Tempe, AZ 85287 (1986-1992)
Doctor of Philosophy, Geology (5/92)
Dissertation: "Frequency dependent electrical properties of olivine and dunite as a function of temperature and oxygen fugacity." Advisor: Dr. James A. Tyburczy
Areas of specialization: Mineral physics, solid state chemistry and defect transport, geophysics.
GPA: Graduate: 3.97/4.0 *Phi Kappa Phi*

The University of Texas at San Antonio, Texas 78249 (1981-1985)
Bachelor of Science, (12/85)
Major: Applied Science GPA: 3.8/4.0 *Summa Cum Laude, Alpha Chi*

Work Experience and Positions Held

Strategic Focus Area Leader, Energy and Climate, Energy and Security Council Member, Lawrence Livermore National Laboratory, Livermore, CA 94551 (2008-present). Plan and develop LLNL's high level investment strategies for future energy and climate thrusts.

Program Leader, E-Program Alternative and Renewable Energy Cycle, Lawrence Livermore National Laboratory, Livermore, CA 94551 (2008-present). Manage and develop energy programs totaling approximately $14M in FY09. Liaison between DOE and industry sponsors and PIs.

Deputy Division Leader for Science and Technology, Atmospheric, Earth, and Energy Division, Lawrence Livermore National Laboratory, Livermore, CA 94551 (2007-present)

Geophysicist, Geophysics and Global Security, Lawrence Livermore National Laboratory, Livermore, CA 94551 (1992-present)

Research Associate, Department of Geology, UC Davis, Davis, CA (2006 to present)

Adjunct Professor, Department of Science and Mathematics, Las Positas Community College, Livermore, CA 94550 (1995-present)

Postdoctoral Research Associate, Geology Dept., Arizona State University, Tempe, AZ 85281 (1992)

Graduate Research Associate/Teaching Assistant, Geology Dept., Arizona State Univ., Tempe, AZ (1987-1992)

Teaching Assistant, Division of Earth and Physical Sciences, Department of Physics, The University of Texas at San Antonio, TX (1982-1985).

Technical Staff Assistant (II, III, IV), Division of Earth and Physical Sciences, Department of Physics, The University of Texas at San Antonio, TX (1982-1983).

Electronic Intelligence Operations Specialist, Joint Electronic Warfare Center. United States Air Force, Kelly AFB, TX (1976-1980, Honorable Discharge).

Recent Honors, Awards, Professional Service

2002-2008	AGU Mineral and Rock Physics, Executive Committee
2008	NASA Tech Briefs Nano-50 Award
2008	LLNL-Directorate Award for Exceptional Service
2008	LLNL-Global Security Silver Award for Radiation Detector Research
2007-2008	Eos Editorial Advisory Board
2005	Geothermal Resources Council Best Paper Award
2004-2007	Eos corresponding editor for Mineral and Rock Physics
2004-2006	Physical Properties of Earth Materials Steering Committee
2004	LLNL- Energy and Environment Directorate Award for mentoring
2002	IUGG EM Workshop Program Committee
2001	Geothermal Resources Council Best Paper Award

Professional Affiliations

American Geophysical Union
Geothermal Resources Council
Environmental and Engineering Geophysical Society

Recent Seminars and Invited Presentations

2009	Frank Press, Erich Bloch, Regional Climate Initiative Briefing
2008	UC Berkeley Seismological Laboratory, Department Seminar
2002-2008	AGU Mineral and Rock Physics, Executive Committee
2007-2008	Eos Editorial Advisory Board
2007	Lawrence Berkeley Laboratory, Department Seminar, Permeability in Olivine-FeS Partial Melts Based on X-ray Computed Micro-Tomography
2007	USGS, Menlo Park, Volcano Hazards Team Seminar Series, Permeability in Olivine-FeS Partial Melts: X-Ray CT and Lattice-Boltzmann Simulations
2005	University of Oregon, Permeability of Olivine-FeS Partial-Melts Based on Tomographic X-ray Imaging
2005	LLNL, Directorate Review, Constraints on the Nature of Terrestrial Core-forming Partial-Melts

Recent Refereed Publications

Cherepy NJ, Payne SA, Asztalos SJ, Hull G, Kuntz JD, Niedermayr T, Pimputkar S, Roberts JJ, Sanner RD, Tillotson TM, van Loef E, Wilson CM, Shah KS, Roy UN, Hawrami R, Burger A, Boatner LA, Choong WS, and Moses WW, Scintillators With Potential to Supersede Lanthanum Bromide, *IEEE Trans. On Nucl. Sci., 33,* 873-880, 2009.

Wright, H. M. N, K. V. Cashman, E. H. Gottsfeld, and J. J. Roberts, Pore Structure of Volcanic Clasts: Measurements of Permeability and Electrical Conductivity, *EPSL,* doi:10.1016/j.epsl.2009.01.023, 2009.

Mathez, E. A., J. J. Roberts, A. G. Duba, A. K. Kronenberg, and S. L. Karner, Carbon deposition during brittle rock deformation: Changes in electrical properties of fault zones and potential geoelectric phenomena during earthquakes, *J. Geophys. Res.., 113, B12*, B12201, 2008.

Hull, G., J.J. Roberts, J.D. Kuntz, S.E. Fisher, R.D. Sanner, T.M. Tillotson, A.D. Drobshoff, S.A. Payne, and N.J. Cherepy, Ce-doped single crystal and ceramic garnets for γ ray detection, *Proc. SPIE, 6706,* 70617, 2007.

Sweeney, H. J., J. J. Roberts, and P. E. Harben, A Study of the Dielectric Properties of Dry and Saturated Green River Oil Shale, *Energy & Fuels, 7*, 150-158, doi:10.1021/ef070150w, 2007.

Kuntz, J. D., J. J. Roberts, M. Hough, and N. J. Cherepy, Multiple synthesis routes to transparent ceramic lutetium aluminum garnet, *Scripta Materilia,* 57, no. 10, 960-963, doi:10.1016/j.scriptamat.2007.07.017, 2007.

Roberts, J.J., J. Siebert, F. J. Ryerson, and J. H. Kinney, Fe-Ni-S Melt Permeability in Olivine: Implications for Planetary Core Formation, *Geophys. Res. Lett, 34*, L14306, doi:10.1029/2007GL030497, 2007.

Wright, H. M. N., J. J. Roberts, and K. V. Cashman (2006), Permeability of anisotropic tube pumice: Model calculations and measurements, *Geophys. Res. Lett., 33*, L17316, doi:10.1029/2006GL027224.

Du Frane, W. L., J. J. Roberts, D. A. Toffelmier and J. A. Tyburczy, Anisotropy of electrical conductivity in dry olivine, *Geophys. Res. Lett.*, 32, L24315, 2005.

4. Facility Capabilities

4.1 Program for Climate Model Diagnosis and Intercomparison

The PCMDI mission is to develop improved methods and tools for the diagnosis and intercomparison of general circulation models that simulate the global climate. PCMDI is the centerpiece of the LLNL climate program, funded through the Office of Biological and Environmental Research in DOE's Office of Science. For the past 20 years PCMDI has provided key scientific contributions to the reports written by the Intergovernmental Panel on Climate Change (IPCC), and PCMDI received a special acknowledgment in the 2007 IPCC Fourth Assessment Report for archiving and distributing over 30 terabytes of climate model output. Karl Taylor, Ben Santer and several other key members of PCMDI were recently recognized by the American Meteorological Society for making it possible for the international climate research community to share models and data through the multi-model dataset archive, maintained by PCMDI at LLNL.

LLNL will be responsible for maintaining and advancing PCMDI's outstanding international reputation for climate research and enhancing the infrastructure that will provide climate model analysis and data distribution capabilities needed by the international climate community for the next round of IPCC reports. PCMDI is a critical data provider for the LLNL energy modeling and analysis teams and provides them with guidance on interpreting climate model results.

4.2 High Performance Computing

BlueGene/L—seventh on the TOP500 list of supercomputers with a sustained world-record speed of 478.2 teraFLOPS—is a revolutionary, low-cost machine delivering extraordinary computing power.

Located in the Terascale Simulation Facility at Lawrence Livermore National Laboratory, BlueGene/L is used by scientists at Livermore, Los Alamos, and Sandia National Laboratories. The 596-teraFLOPS machine handles many challenging scientific simulations, including molecular dynamics; three-dimensional (3D) dislocation dynamics; and turbulence, shock, and instability phenomena in hydrodynamics. It is also a computational science research machine for evaluating advanced computer architectures.

IBM recently delivered a 500-teraFLOPs BlueGene/P system known as Dawn that will help lay the applications foundation for the 20-petaFLOP Sequoia system. Sequoia is scheduled for delivery in 2011, with full deployment in 2012.

Developed by the IBM Watson Research Center in partnership with many, BlueGene/L is scaled up with a few unique components and IBM's system-on-a-chip technology developed for the embedded microprocessor marketplace. The computer's nodes are interconnected in three different ways instead of the usual one. Using a cell-based design, BlueGene/L is a scalable architecture in which the computational power of the machine can be expanded by adding more building blocks, without introduction of bottlenecks as the machine scales up.

Key application results on BlueGene/L are pointing to a qualitative change in the way computational science can be performed. With a rapid time-to-solution, scientists can perform a new run every day, make numerous investigations, and explore multiple alternatives. An entire scientific study can now be performed in the same time as just one science run required only a year ago. BlueGene/L is already making an impact on key NNSA missions and exploring one route toward cost-effective petaFLOPS computing capabilities.

Two new IBM supercomputing systems will be added soon. Sequoia will be a 20 petaFLOPS system based on future BlueGene technology, with delivery in 2011 and deployment in 2012. An initial delivery system, Dawn, a 500 teraFLOPS BlueGene/P system, has been delivered and installed. Dawn will lay the applications foundation for multi-petaFLOPS computing on Sequoia.

Sequoia is expected to be the most powerful supercomputer in the world and will be approximately 10 times faster than today's most powerful system. To put this into perspective, if each of the 6.7 billion people on earth had a hand calculator and worked together on a calculation 24 hours per day, 365 days a year, it would take 320 years to do what Sequoia will do in one hour.

The Sequoia systems will be focused on strengthening the foundations of predictive simulation through running very large suites of complex simulations called uncertainty quantification (UQ) studies.

Sequoia will have 1.6 petabytes of memory, 96 racks, 98,304 compute nodes, and 1.6 million cores. Though orders of magnitude more powerful than such predecessor systems as ASC Purple and BlueGene/L, Sequoia will be 160 times more power efficient than Purple and 17 times more than BlueGene/L.